MASTER

XIII

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
NATIONAL AGRICULTURAL ADVISORY SERVICE
South West Province

Irrigation Needs in the South West Province

W. H. Hogg

INTRODUCTION

During the last few years an increasing interest has been shown in estimating the water needs of growing crops by using standard climatic data. This method is based on the theoretical work of Dr. H. L. Penman (1948). A full account of the method is given in M.A.F.F. Technical Bulletin No.4, "The Calculation of Irrigation Need" (1954), with examples of water balance sheets.

It is clear from this Bulletin that irrigation needs are greatest in the South East of England, but this does not imply that irrigation is unnecessary in the South West Province. In fact, crop production, including grass, could be improved by irrigation in most years over much of the low-lying parts of the Province, and the object of this paper is to show precisely to what extent rainfall fails to meet the needs of the growing crops. This has been done by compiling water balance sheets for eleven places for each of the years 1930-49. The most important facts from these balance sheets are summarised in various tables. These tables provide basic data which can be used in estimating whether a farmer or grower is likely to be able to irrigate his land in the worst years with existing water supplies, or how much equipment will be necessary to irrigate a given acreage in the driest season.

2. ASSUMPTIONS MADE IN THE CALCULATION OF IRRIGATION NEEDS

The main assumption made in this paper is that the Penman method gives approximately the correct irrigation needs for growing crops. But the Penman method itself is based on a number of assumptions which must be borne in mind when using the data. The chief of these are:-

(i) The crop effectively covers the ground, i.e. the ground would appear more or less green if seen from the air. Thus, the method cannot strictly be applied to fallow, or to an area newly planted with widely spaced seedlings or transplants.

(ii) Growth must not be limited by lack of water. This does not mean that the soil must be at field capacity, but rather that the roots are able to supply the plant with as much water as it needs, thus avoiding any check in transpiration.

(iii) The figures are applicable to a wide range of soil types, though no doubt some correction is needed when dealing with particularly good or very bad soils. Such correction at present can only be qualitative.

(iv) All water infiltrates and is held by the soil till field capacity is reached. Some correction may, however, be needed for run-off in heavy rain; this correction can only be a rough estimate based on observation.

(v) The root constant is roughly known for various groups of crops. The root constant is defined as the maximum soil moisture deficit that can be built up without checking the transpiration. Experiments are now taking place which will give more precise information on root constants for various crops. The following extract from M.A.F.F. Technical Bulletin No. 4 gives a fair idea of our present state of knowledge.

"The only crop for which the order of magnitude of the root constant is known is grass: the value is about 3 to 5 inches (i.e. equivalent to a deficit of this value as the maximum allowable for unchecked transpiration). For shallow-rooted market-garden crops, or seedlings of any kind, it may be only 1 to 2 inches, while for deep-rooted crops, including trees, it may be 8 to 10 inches or more. Nevertheless, in poorly drained soils, particularly where roots are subject to winter killing, the root systems of deeply rooting perennials such as fruit trees may be confined to the surface layers and unable to reach the water reserves below. Under these conditions, trees suffer badly from drought, and the root constant may be of the order of 3 inches or less".

Recently there has been a tendency to apply water before the full root constant has been reached, and it has been recommended that the aim should be to keep the maximum moisture deficit close to half the root constant. Thus, taking the root constant of grass as 4 inches, this method would attempt to keep the moisture deficit at about 2 inches. This can be done by allowing the deficit to fall to $2\frac{1}{2}$ inches and applying 1 inch. The chief advantage claimed for this method is that it allows an adequate safety margin, and experiments now in progress confirm its soundness.

3. FREQUENCY OF IRRIGATION NEED

Fig. I has been taken from M.A.F.F. Technical Bulletin No. 4 and it gives a general idea of the frequency of irrigation need with a root constant of 3 inches. Theoretically, this means that the soil is not allowed to dry out beyond the point where three inches of rainfall (or irrigation) would be necessary to bring it back to field capacity. In practice, of course, it may be allowed to fall to $3\frac{1}{2}$ or 4 inches below field capacity and then watered to bring it to 2 or $2\frac{1}{2}$ inches below field capactiy. As explained on pages 9 and 13 of the Bulletin, this map is based on seasonal balance sheets; however, marked dry spells may occur during the season which are later swamped by heavy rainfalls. If a balance is struck at the end of the season it may well seem that there has been no water shortage but, in fact, the plants may suffer severe damage in the drought which will not be repaired by subsequent rainfall.

In the tables which follow, the irrigation need has been computed fortnightly from the beginning of April to the end of September. In the original computations, the three root constants 1 inch, 2 inches and 3 inches were used, and these are all given in the tables where practicable. In addition, an increasing soil deficit was used, starting at nil at the beginning of the season and increasing by $\frac{1}{4}$ inch every fortnight to become 3 inches by the end of the season.

Table I shows the number of years in 20 when the total irrigation needs exceed 0, 2, 4 and 6 inches for the various root constants. The left hand block of figures shows the number of years when irrigation was necessary. The values in the third column of this block refer to a root constant of 3 inches and can, therefore, be used in conjunction with Figure 1 to show the effect of taking account of periods of dry weather as they occur. The differences at many places are striking. At Bude, for example, the map gives an estimate of less than 10 years in 20, but the rainfall figures show a need in 17 years, the same frequency as at Cheltenham. This does not mean irrigation is as necessary at Bude as at Cheltenham for other figures in the table show that Bude needs more than 2 inches in 14 years, more than 4 inches in 6 years and more than 6 inches in 1 year only. At Cheltenham, the corresponding figures are 15, 10 and 3 years.

TABLE I. NUMBER OF YEARS IN 20 WHEN THE IRRIGATION NEEDS EXCEED STATED AMOUNTS

Irrigation need	0 inch				2 inches				4 inches				6 inches			
Root Constant	1"	2"	3"	Inc.	1"	2"	3"	Inc.	1"	2"	3"	Inc.	1"	2"	3"	Inc.
Cheltenham	19	19	17	20	18	17	15	17	16	13	10	12	10	7	3	5
Long Ashton	19	19	17	19	18	13	6	14	7	3	3	3	3	1	0	1
Bromham	19	19	16	20	18	16	13	16	14	7	4	8	4	2	2	2
Porton	20	20	18	20	18	17	16	18	17	14	13	10	10	7	5	7
Cannington	20	19	17	20	18	17	15	16	16	10	4	9	5	2	1	1
Yeovil	20	18	17	20	17	16	11	17	12	7	4	7	5	3	2	2
Swanage	20	20	18	20	18	18	17	17	17	15	13	15	13	12	7	9
Exmouth	20	19	18	20	18	16	14	17	15	13	7	12	7	4	3	4
Plymouth	19	18	15	19	16	13	11	14	12	8	3	8	5	2	1	2
Bude	20	17	17	20	17	16	14	16	15	8	6	9	6	3	1	3
Penzance	19	18	15	20	15	11	7	13	8	4	3	4	3	2	1	2

The remaining blocks in the table show how often the total requirements of irrigation water may be expected to exceed 2", 4" and 6 inches. The values naturally vary according to the root constant used. Many growers would probably be working to a root constant of about 1 inch, for which most parts of the Province can expect a requirement of at least 4 inches in 12 or more years out of 20. The exceptions are Penzance and, surprisingly, Long Ashton. It must be emphasized that these requirements are for supplying water to what are substantially "green cover crops". It does not include water which may be used for cultural purposes such as the preparation of land for transplanting, or for pulling onions. If a grower installs irrigation equipment, therefore, he will probably use more water than would be indicated in Table I (and other tables). On the other hand, farmers with equipment will probably use about the amount of water indicated by the tables, for they will be concerned in the main with green cover crops and also, they are far less likely to use water for purposes other than the irrigation of crops.

4. ADEQUACY OF WATER SUPPLIES

The main purpose of Table I is to enable a decision to be made on the desirability of irrigation for a given purpose at a given place. If irrigation is desirable, then two further questions have to be considered, viz., the adequacy of the water supply and the size of equipment to be installed.

The adequacy of the water supply can be determined by estimating the probable consumption in the 10 driest seasons out of 20, and also in the driest season *

Table II gives this information for 4 root constants. Under each root constant the first value is the minimum amount of water required in any of the 10 driest years; the second value is the maximum water requirement in any one of the 20 years analysed.

* The term driest season used here does not mean the season with the least rainfall, but the one with the greatest irrigation need. These are not necessarily the same, for the irrigation need depends partly on the distribution of the rainfall during the season.

TABLE II

(a) Minimum irrigation in the 10 driest years
(b) Maximum irrigation required in 20 years

Root Constant	1 inch		2 inches		3 inches		Increasing	
	a	b	a	b	a	b	a	b
Cheltenham	6.1	9.5	5.1	8.5	4.1	7.5	4.7	8.0
Long Ashton	3.9	7.5	2.6	6.4	1.5	5.4	2.8	6.3
Bromham	4.8	9.2	3.5	8.2	2.5	7.2	3.4	7.5
Porton	6.8	11.7	5.3	10.7	4.3	9.7	5.1	9.9
Cannington	5.2	9.3	4.2	8.3	3.2	7.3	3.9	7.5
Yeovil	4.7	8.6	3.2	7.6	2.2	6.6	3.2	7.1
Swanage	7.3	11.7	6.1	10.7	5.1	9.7	6.0	10.2
Exmouth	5.6	11.0	4.6	10.0	3.6	9.0	4.3	9.5
Plymouth	4.7	8.2	3.7	7.2	2.7	6.2	3.9	7.1
Bude	4.6	8.1	3.5	7.1	2.5	6.1	3.5	6.6
Penzance	4.0	9.3	2.8	8.3	1.5	7.3	2.6	8.0

The market garden area of South Dorset may be taken as an example of the way in which Table II may be used. Assuming a root constant of 1 inch, 7.3 inches or more of irrigation water will be required in 10 years out of 20 and 11.7 inches in 1 year out of 20. As 1 inch of water is 22,622 gallons per acre, it is simple to calculate that 10 years out of 20 at least 1.65 million gallons for 10 acres will be needed, and once in 20 years 2.65 million gallons are necessary.

This problem of adequacy of supplies may be regarded from another angle, that of peak rather than overall requirements. As it is assumed that a balance is made every fortnight and irrigation applied then if necessary, a knowledge of the greatest single application in individual years will help to assess the peak load.

Table III (Columns (a)) contains the greatest single application over a 20-year period for the 4 root constants.

These values suggest that there must be sufficient water available to supply 2-2½ inches over the irrigated area within a few days. It is interesting to note that the requirements are about the same whatever the root constant - in other words, the maximum requirements for horticultural crops will be very similar to those for agricultural crops although the total requirements for horticultural crops will exceed those for agricultural crops because watering will be started earlier.

TABLE III

(a) Maximum fortnightly requirements in 20 years
(b) Maximum requirements in 2 successive fortnights

Root constant	1 inch a	1 inch b	2 inches a	2 inches b	3 inches a	3 inches b	Increasing a	Increasing b
Cheltenham	2.3	3.9	2.3	3.9	2.3	3.9	2.1	3.4
Long Ashton	2.4	3.9	2.4	3.7	2.2	3.7	1.9	3.4
Bromham	2.5	4.3	2.5	3.9	2.5	3.6	2.3	3.5
Porton	2.5	4.1	2.5	4.1	2.5	4.1	2.2	3.6
Cannington	2.6	4.2	2.6	4.2	2.6	4.2	2.3	3.7
Yeovil	2.4	3.8	2.4	3.8	2.4	3.8	2.2	3.3
Swanage	2.5	4.3	2.5	4.3	2.5	4.2	2.3	3.7
Exmouth	2.2	3.8	2.2	3.8	2.2	3.7	2.0	3.3
Plymouth	2.0	3.4	2.0	3.4	2.0	3.4	2.0	2.9
Bude	2.1	3.5	2.1	3.3	2.1	3.3	1.9	3.0
Penzance	1.9	3.4	1.9	3.4	1.9	3.4	1.6	2.9

It may well happen that one heavy demand will be followed by another before there has been much replenishment of supply. This is likely during a long drought and columns (b) in Table III give the maximum demand for any two successive fortnightly applications, i.e. the maximum requirements within a period of 2-3 weeks, allowing a few days for the application of the water.

Even this does not give a complete picture, for the effects of a very dry period on water supply could be greater after a pre-existing dry spell than following a wet spell. Probably the clearest indication of the worst to be expected is given by the fortnightly irrigation needs for the year when most irrigation was needed. Other years will not exactly follow this pattern but it will serve as a guide for summers when there is a great need for irrigation. The values are given in Table IV for a root constant of 2 inches. As can be seen from Table II, the total irrigation need will be about 1 inch less with a 3 inch root constant and about 1 inch more with a 1 inch root constant.

TABLE IV (see over)

5. SIZE OF EQUIPMENT

If the supply of water is adequate for all likely requirements, the only remaining factor to be considered is the size of equipment. This, in turn, is bound up with the area to be irrigated. A plant designed to provide an inch of irrigation water to an acre in 10 hours can, in 20 hours, supply 2 inches to one acre or 1 inch to 2 acres. Table III shows that the maximum fortnightly application (root constant 2 inches) is about $2\frac{1}{2}$ inches. If, therefore, it is planned to irrigate 10 acres, this plant would have to be kept working for 250 hours to supply the necessary water (say 25 days at 10 hours/day). Clearly, more equipment is necessary; if the equipment were increased five-fold the greatest water need could be met in 50 hours, say 5 days, plus any time used in moving the equipment.

Reference: Penman H.L. Proc. Roy. Soc. 193A, 1948, pp. 120-145

Meteorological Office,
Agricultural Branch,
Bristol

February, 1956.

TABLE IV

IRRIGATION SCHEDULES IN YEARS OF GREATEST NEED

ROOT CONSTANT 2 INCHES

	Cheltenham	Long Ashton	Bromham	Porton	Cannington	Yeovil	Swanage	Exmouth	Plymouth	Bude	Penzance
Year	1949	1933	1949	1940	1933	1949	1949	1949	1940	1949	1940
PERIOD											
April 1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
May 1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
16-31	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5
June 1-15	0.3	1.0	0.7	2.0	1.4	1.2	1.8	1.4	1.7	1.0	1.9
16-30	1.8	0.7	1.8	1.4	0.4	1.8	1.9	1.9	1.1	1.7	0.9
July 1-15	2.0	0.1	2.1	0.7	1.2	1.3	2.1	1.9	0.4	1.1	1.1
16-31	1.6	1.7	0.3	1.5	1.6	0.7	1.7	1.0	1.0	0.9	0.5
August 1-15	1.5	2.0	1.4	1.6	2.1	1.3	1.9	1.9	1.5	1.1	1.9
16-31	1.3	0.5	1.2	1.5	1.1	1.3	1.3	1.5	1.5	1.3	1.5
Sept. 1-15	0.0	0.4	0.7	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0
16-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL.	8.5	6.4	8.2	10.7	8.3	7.6	10.7	10.0	7.2	7.1	8.3

Frequency of Irrigation Need Years in Ten

NOR.
CUM.
DUR.
WEST.
Y.N.R.
Y.E.R.
Y.W.R.
LAN.
ANG.
CHES.
FL.
CARN.
DEN.
DER.
NOT.
LINC.
STAF.
MER.
SHR.
LEIC.
RUT.
MONT.
WAR.
NOR.
HUN.
CAM.
SUF.
RAD.
WOR.
CARD.
HERE.
BED.
BREC.
PEM.
CARM.
OX.
BUCK.
ESS.
GLOS.
HERT.
MON.
GLAM.
MID.
LON.
BERK.
WILT.
SUR.
KENT.
SOM.
HAMP.
SUS.
DEV.
DOR.
CORN.

5 5 5 5 6 7 8 9

<5 5-6 6-7 7-8 8-9 >9